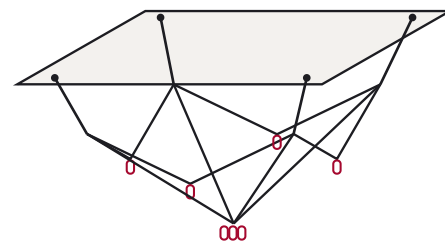


ACTIVITY 2 · CHAPTERS 02 AND 03 · THE HANGING MODEL

An upside-down church

To design the church at the Colònia Güell, Gaudí hung a model made of strings and little bags of lead shot from the ceiling, and worked on it for about ten years. He photographed it, turned the photo upside down and drew the building on top. You will make a small one with thread and paper clips.



Name _____

Class _____

Date _____

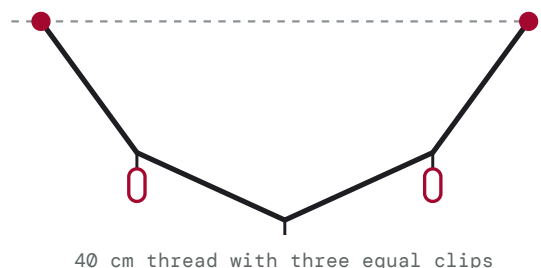
TIME Part A, 25 minutes. Part B, a 50-minute lesson.

GROUPS Groups of three or four

YOU NEED Thick sewing thread or thin string (about 3 m), around thirty small paper clips, a ruler, a protractor, an A3 sheet (or two A4 sheets taped together), a shoebox lid, sticky tape, scissors, two piles of books about 30 cm high, a phone or tablet to take photos and the template on page 3. To make the holes, an awl, to be used by an adult.

A One thread and three clips

- 1 Tie a thread between two points at the same height and 30 cm apart, so that 40 cm of thread hangs between them: two pins in a cork board, or two equal piles of books.
- 2 Bend three paper clips into hooks and hang them on the thread at 10, 20 and 30 cm from one end.
- 3 Hold the A3 sheet behind the thread and mark where the clips and the two ends are. Join the marks with the ruler.



40 cm thread with three equal clips

A1 Between two clips, does the thread curve or run straight? Where does it change direction?

A2 Measure with a protractor the angle the thread makes at each clip. Then hang a second clip next to the first and measure again.

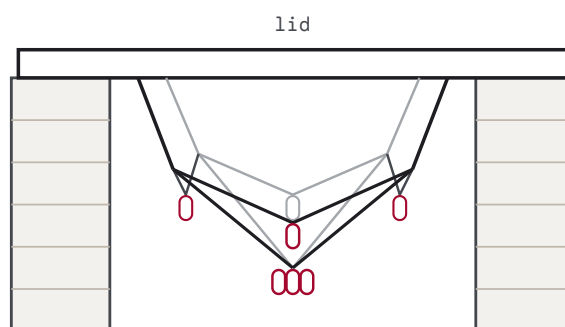
	Clip1	Clip2	Clip3
One clip at each point			
Two clips at the first point			

A3 What happens to the angle when there is more weight? And to the rest of the thread?

A4 Turn the drawing upside down and imagine it made of stone, with the weights on top: each section pushes on the next and the whole thing stands up. Engineers call it a funicular polygon. If you wanted to put more weight at one point, what would the angle there have to be like?

B The church in a box

- 1 Cut out the template on page 3, leaving a 1 cm margin around the square, and stick it in the middle of the outside of the lid. An adult makes a hole at each point C.
- 2 Cut the threads: four columns of 10 cm, four arches of 24 cm and two diagonals of 32 cm. These lengths include the knots.
- 3 Push each column through a hole and tie a big knot on top. Tie a paper clip to the other end: it will be a joint of the net.
- 4 Tie each arch between two neighbouring clips and each diagonal between two opposite clips. Where the diagonals cross, tie them together.
- 5 Put the lid on the piles of books with the threads hanging down. Hang one clip from the middle of each arch and three from the centre.



the lid on two piles of books, with the net hanging underneath

B1 Look at the column threads. Are they vertical? Which way do they lean?

B2 Hang three more clips from the centre. What do the columns do? And the arches?

B3 Take a photo from the side, with the phone level with the net, and rotate it 180°. Where are the arches, the columns and the vault?

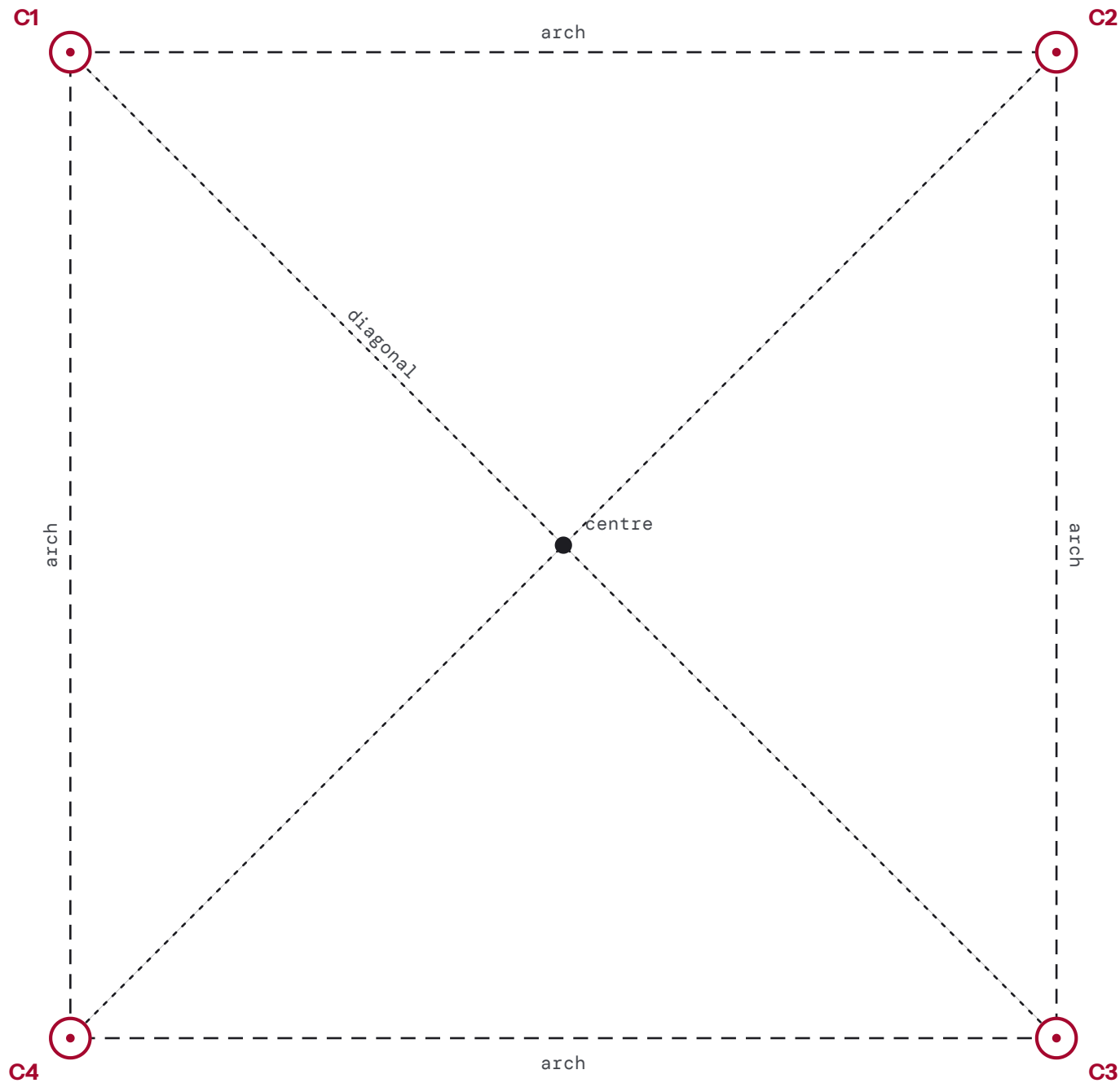
B4 Print the rotated photo, or trace it onto tracing paper held against the screen, and draw walls, windows and a door on it. Gaudí did exactly this on the upside-down photos of his model. The Museu Nacional d'Art de Catalunya keeps two of them.

GOING FURTHER

Move a single weight and watch what moves: everything does. That is why Gaudí's model worked like a computer. When he changed one load, gravity recalculated the whole church in a few seconds.

Cut out the template with a 1 cm margin around the square. Holes only with an adult.

Floor plan of your church · stick it on the outside of the lid



C1-C4: holes for the columns · dotted lines: arches and diagonals

 check: should measure 4 cm

Thread	How many	Length with knots	Goes from
Column	4	10 cm	a hole C to a clip
Arch	4	24 cm	a clip to the next clip
Diagonal	2	32 cm	a clip to the opposite clip

An upside-down church

SOLUTIONS AND NOTES

AIMS

See that a loaded thread forms straight sections, relate weight to angle, see that in a net everything depends on everything else, measure angles and make 180° turns.

MATHS TOPICS

Geometry (rotations) · Measurement (angles). Links with Design and Technology: structures, tension and compression.

TIPS

- A thread that doesn't stretch, such as thick cotton, gives cleaner shapes. Use identical clips so they weigh the same.
- To save time, you can stick the templates on and make the holes before part B. The lid needs to be at least 18 cm wide; if it is smaller or bends, a piece of thick cardboard does the same job. If the centre clips touch the table, add a book to each pile.
- For the photo, rest the phone on a pile of books, level with the threads. Any photo editor will rotate the image by 180° .
- Part A can use the cork board from activity 1.

GAUDÍ'S MODEL

Gaudí received the commission in 1898 and worked with the model for about ten years, at 1:10 scale and loaded with little bags of lead shot. Building began in 1908 and stopped in 1914, and only the crypt was built. Two of the upside-down photographs he drew on in charcoal and chalk, one of the outside and one of the inside, are in the Museu Nacional d'Art de Catalunya. In 1982–83 a team at Frei Otto's Institut für leichte Flächentragwerke in Stuttgart rebuilt the model, which is now in the Sagrada Família museum. The exhibition in the old cooperative building at the Colònia Güell has a reproduction.

SOLUTIONS

- **A1** Between clips the thread runs straight. It changes direction at each clip.
- **A2** With equal clips, calculation gives about 151° at the outer clips and about 131° at the middle one. With two clips at the first point, about 136° , 139° and 154° . Real measurements can be a few degrees off.
- **A3** The more weight, the sharper the angle. And the whole thread moves, not just that point.
- **A4** Sharper, more pointed.
- **B1** No. They lean towards the centre, because the arches and diagonals pull them inwards.
- **B2** The columns lean a little further in and the arches are pulled towards the centre. The changes are only a few millimetres: compare two photos taken from the same spot.
- **B3** In the rotated photo the lid is the floor. The columns rise leaning inwards, and the arches and diagonals become arches and a vault, highest at the centre.

To follow up: chapters O2 and O3 at crm.cat/les-matematiques-de-gaudi, with an interactive string and net; the MNAC online exhibition "Gaudí, the Architect", showing both drawn-on photographs; and the video "El mètode de models invertits. La Colònia Güell" (in Catalan) at educa.sagradafamilia.org.

FURTHER READING

- Tomlow, J. (1989). *Das Modell / The Model / El modelo* (IL 34). Stuttgart: Institut für leichte Flächentragwerke. Free to read on the ILEK website.
- Huerta, S. (2006). "Structural Design in the Work of Gaudí". *Architectural Science Review*, 49(4), 324–339.
- Roca i Fabregat, P. (2005). *Antoni Gaudí i el disseny estructural*. Barcelona: Institut d'Estudis Catalans. In Catalan, free to read on the IEC website.

The full bibliography, with links, is at crm.cat/les-matematiques-de-gaudi.